SEMICONDUCTOR DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The disclosure of Japanese Patent Application No. 2013-135092 filed on Jun. 27, 2013 including the specification, drawings and abstract is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The present invention relates to a semiconductor device and for example a semiconductor device containing a capacitive touch sensor circuit.

[0003] Capacitive touch sensor circuits are commonly utilized in the touch key and touch screen technical field. U.S. Pat. No. 8,089,289 discloses a structure for modulating a signal output from the switching capacitance circuit into a digital signal by using a sigma-delta modulator circuit. U.S. Pat. No. 7,312,616 discloses a structure that measures the value of a target measurement capacitance by comparing on a comparator, a reference voltage with a terminal voltage for a target measurement capacitance that is repeatedly charged and discharged at a specified frequency. Japanese Unexamined Patent Application Publication No. 2008-199408 discloses an oscillator whose frequency changes by touching or non-touching from an operating section and a structure for detecting a change in frequency of frequency signals output by the oscillator.

SUMMARY

[0004] As disclosed in U.S. Pat. No. 8,089,289, a technology for measuring a capacitance value by utilizing a comparator to compare a reference voltage with a detection voltage generated based on a periodic charge-discharge current is a commonly used technology. The comparator is a circuit for judging tiny voltage differences between the detection voltage and the reference voltage, and converting those judgment results into a digital signal. Noise superimposed on a system containing a sigma-delta modulator circuit, exerts an effect on the tiny voltage differences, inducing decision errors in the comparator.

[0005] The sigma-delta modulator circuit contains a structure that samples the output from the comparator by way of the clock so deviations in the sampling results caused by noise, will appear as an offset in the comparator input, and cause a drop in measurement accuracy. Other issues and new features will become readily apparent from the description in the specification and the accompanying drawings.

[0006] According to an aspect of the invention, a semiconductor device includes a terminal, a power supply voltage dropping circuit that generates a constant voltage, a switch circuit to periodically apply a constant voltage to a terminal in response to a first clock, a first current-controlled oscillator circuit, and a first counter; and in which the power supply voltage dropping circuit supplies a first current to the switch circuit, the first current-controlled oscillator circuit generates a second clock whose frequency changes in response to the value of the first current, and the first counter counts the number of second clocks within the counting time.

[0007] According to the aspect of the invention, the effects due to noise are removed during detecting of fluctuations in capacitance from the touch electrode and maintain the decision accuracy regardless of whether the touch electrode is touched or not.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a structural block diagram of the semiconductor device of a first embodiment;

[0009] FIG. **2** is a circuit diagram of the current-controlled oscillator circuit contained in the semiconductor device of the first embodiment;

[0010] FIG. **3** is a circuit diagram of the switch circuit of the semiconductor device of the first embodiment;

[0011] FIG. **4** is a characteristic diagram of the current-controlled oscillator circuit contained in the semiconductor device of the first embodiment;

[0012] FIG. **5** is a block diagram of the semiconductor device of a first modification of the first embodiment;

[0013] FIG. **6** is a drawing for describing the function of the constant current circuit contained in the semiconductor device of the first modification of the first embodiment;

[0014] FIG. **7** is a drawing for describing the effect of the constant current circuit contained in the semiconductor device of the modification of the first embodiment;

[0015] FIG. **8** is a block diagram of the semiconductor device of the second modification of the first embodiment;

[0016] FIGS. **9**A, **9**B, and **9**C are drawings for describing the function of the current-controlled oscillator circuit contained in the second modification of the first embodiment, in which FIG. **9**A is a drawing for showing the fluctuation state in the count output from the counter due to the operating condition of semiconductor device, FIG. **9**B is a drawing for describing the relation between the currents applied to the current-controlled oscillator circuit, and FIG. **9**C is a drawing for describing the fluctuation in the count of the counter for TYP condition and BEST condition.

[0017] FIG. **10** is a block diagram of the semiconductor device of a second embodiment;

[0018] FIG. **11** is a circuit diagram of the current-controlled oscillator circuit contained in the semiconductor device of the second embodiment;

[0019] FIG. **12** is a block diagram of the semiconductor device of a third embodiment;

[0020] FIG. **13** is a structural view of the touch screen mounting the semiconductor device of the third embodiment;

[0021] FIG. **14** is an output waveform drawing from the switch circuit and the output buffer contained in the semiconductor device of the third embodiment; and

[0022] FIGS. **15**A and FIG. **15**B are diagrams for describing the method for judging whether or not there is a touch by the switch circuit contained in the semiconductor device of the third embodiment, in which FIG. **15**A shows the parasitic capacitance distribution during non-touching between the touch electrodes, and FIG. **15**B shows the parasitic capacitance distribution during touching between the touch electrodes.

DETAILED DESCRIPTION

[0023] The embodiments are described next while referring to the drawings. When describing quantities and amounts in the embodiment description, unless stated otherwise, the invention is not necessarily limited to the stated quantities and amounts. In the drawings for the embodiment,